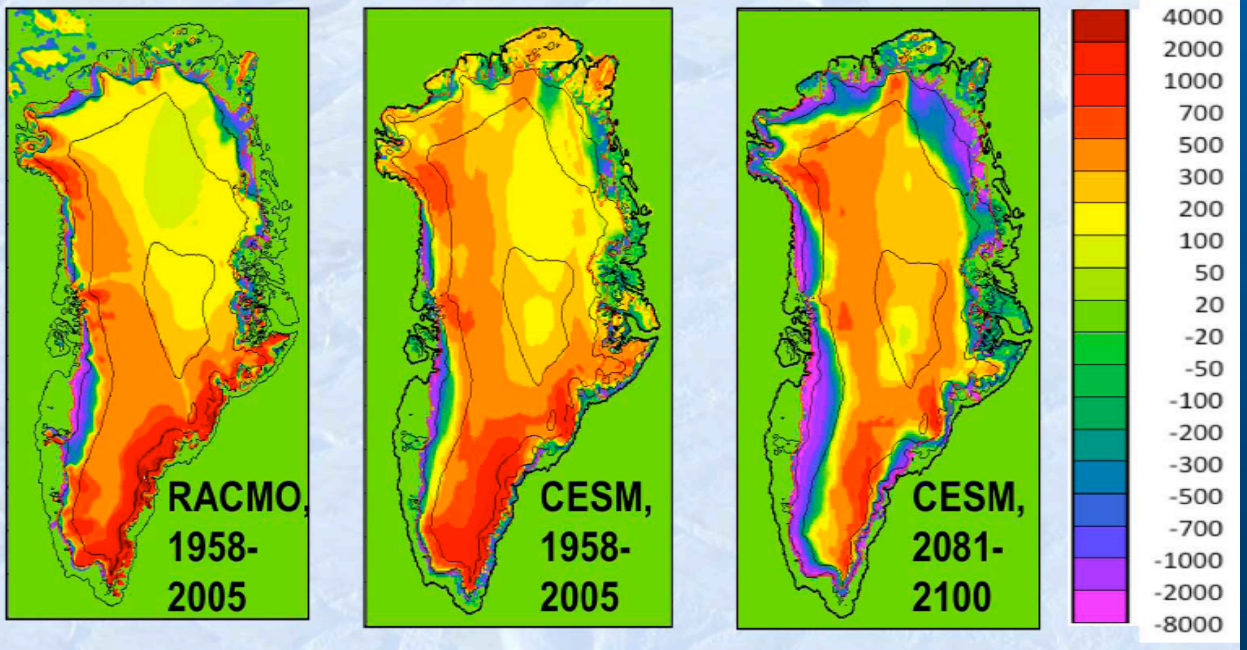
Ice Sheets in the Community Earth System Model

William Lipscomb
Los Alamos National Laboratory
Lipscomb@lanl.gov

Ice sheets in CESM 1.0

- CESM 1.0 (released in 2010) includes the Glimmer Community Ice Sheet Model (Glimmer-CISM)
- Also includes a surface-mass-balance scheme for ice sheets in the Community Land Model (CLM)
  - Multiple elevation classes for improved accuracy
- Work to date has focused on Greenland's surface mass balance; good agreement with regional climate models.

Greenland surface mass balance (mm/yr).
Left: RACMO regional climate model.
Center: CESM, 1958-2005 mean.
Right: CESM, 2081-2100 mean, RCP8.5 scenario.
Red = net accumulation
Blue = net ablation
(Courtesy of M. Vizcaíno)



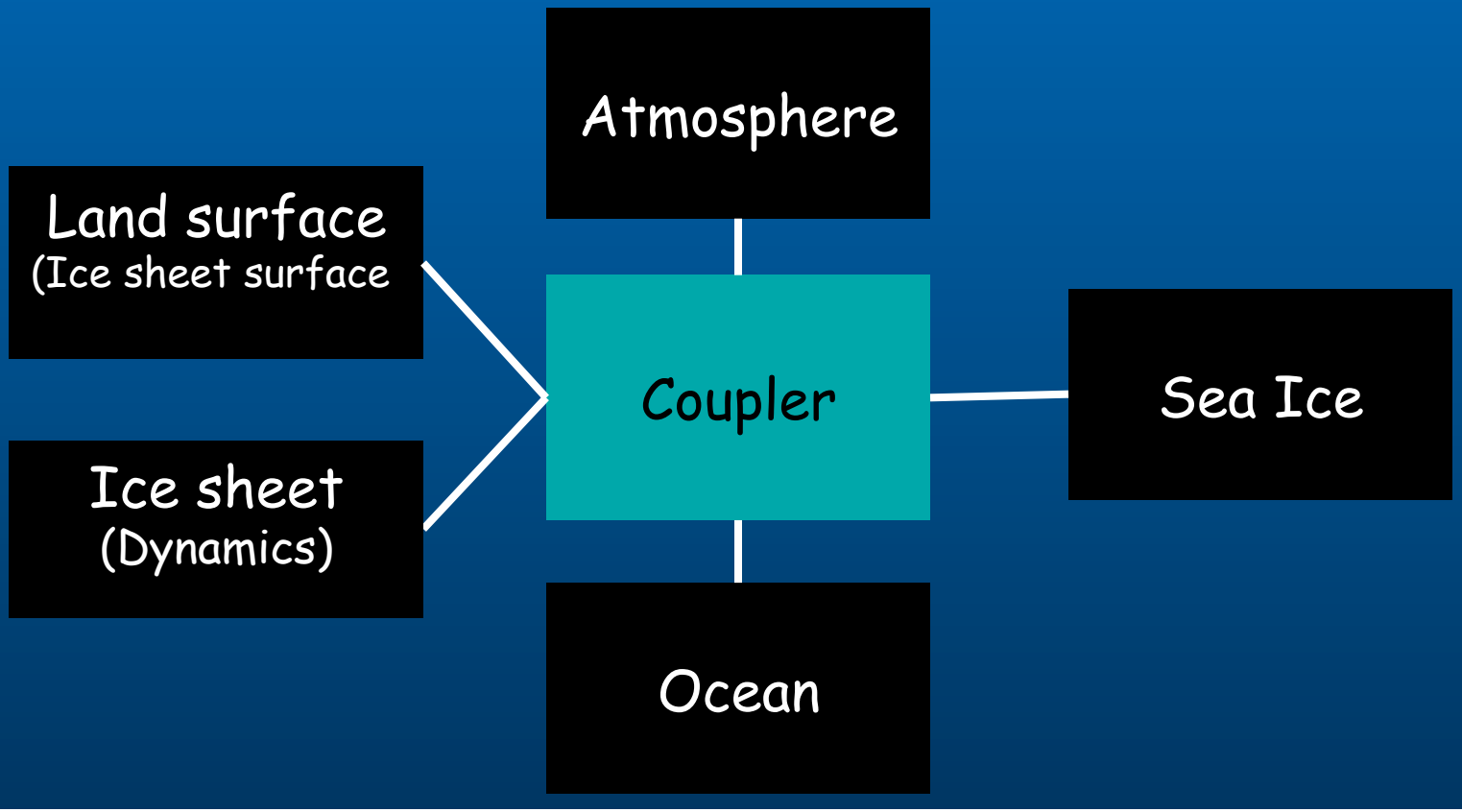
Current status of ice sheets in CESM

Land -> Ice sheet (10 classes)

- Surface mass balance
- Surface elevation
- Surface temperature

Ice sheet -> Land (10 classes)

- Ice fraction and elevation
- Runoff and calving fluxes
- Heat flux to surface



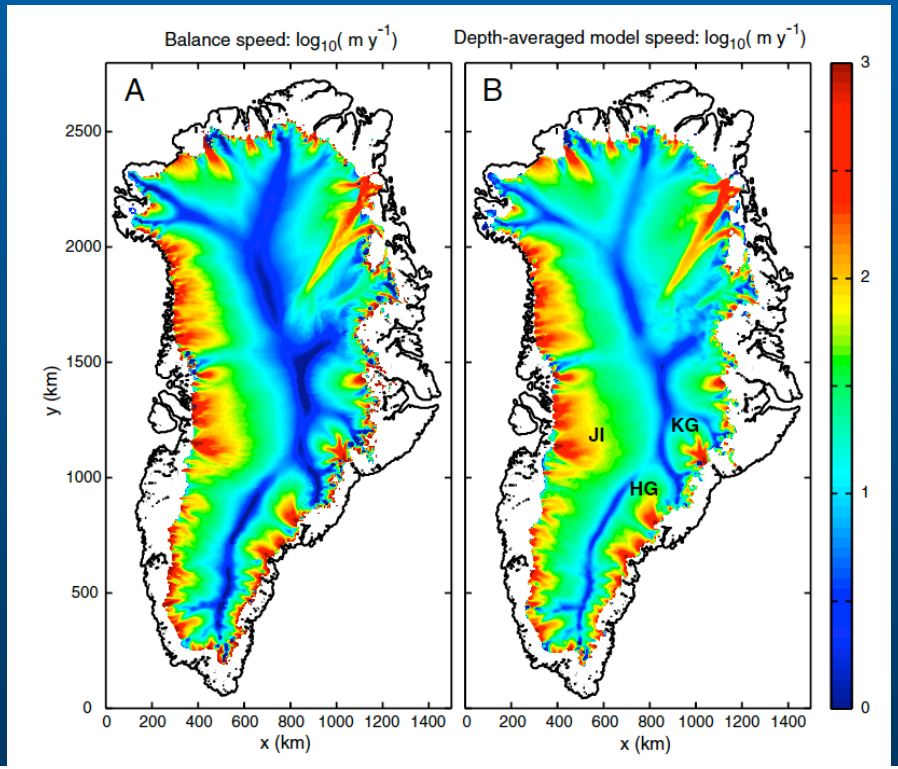
Glimmer-CISM 2.0

- Glimmer-CISM version 2.0 to be released imminently
  - Includes parallel, higher-order Payne-Price velocity solver (3D Blatter-Pattyn) using Trilinos software, Jacobian-free Newton-Krylov methods
  - Version with fully distributed parallelism (including mass and energy transport) is nearly complete
  - Will be coupled to CESM

  - The higher-order model has been used to project committed sea-level rise from the Greenland ice sheet (Price et al. 2011)

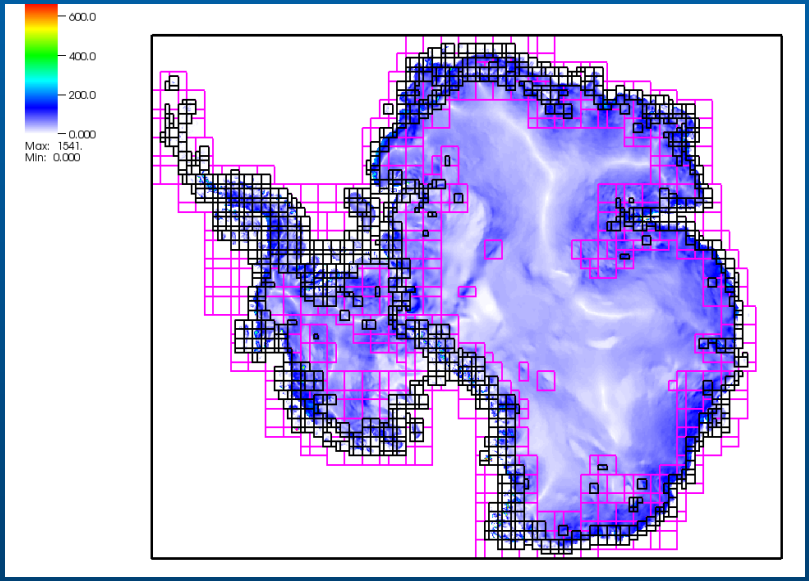
Left: Balance speed inferred from observations

Right: Depth-averaged model ice speed

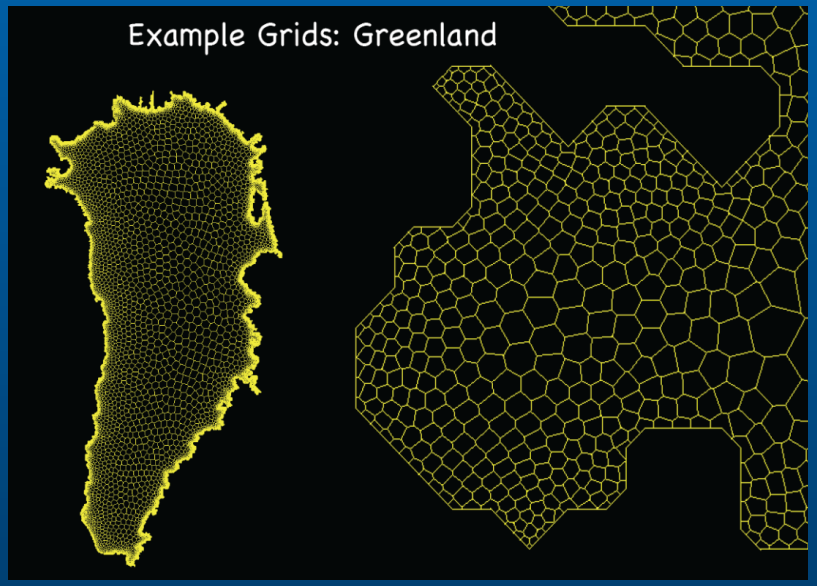


New dynamical cores

- The Berkeley ISICLES project (BISICLES) has developed a parallel, higher-order dynamical core (vertically integrated “L1L2”) based on Chombo adaptive-mesh-refinement software.
  - Has been used to study the acceleration of Pine Island Glacier in West Antarctica (Cornford et al., 2011)
- Another group has developed a hierarchical (Stokes, 3D BP, etc.) finite-element solver (FELIX) on a variable-resolution, unstructured mesh.



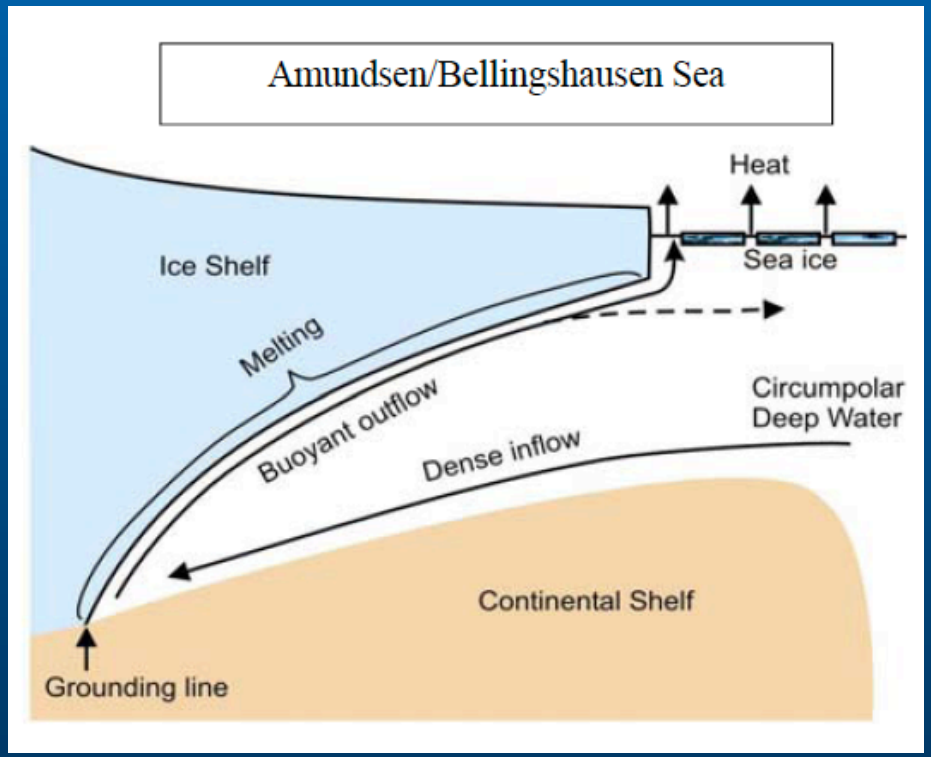
Antarctic ice speed with higher-order solver on a fully adaptive mesh. (Courtesy of D. Martin)

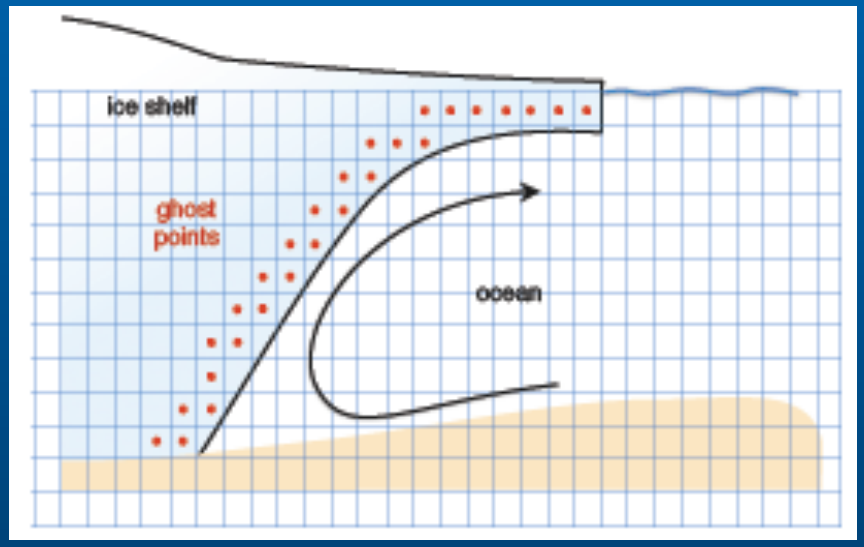


Sample variable-resolution mesh for the Greenland ice sheet

Ice-ocean coupling

- As part of the DOE IMPACTS project on abrupt climate change, we are modifying POP (the ocean component of CESM) to simulate ocean circulation and heat/mass exchange beneath floating ice.
  - Using immersed boundary methods at the moving interface
- We plan to couple oceans and ice sheets dynamically in CESM, to study mechanisms of marine ice sheet instability.





Left: Schematic of Circumpolar Deep Water delivering heat to the grounding line

Right: Sub-ice-shelf circulation using immersed boundary method with ghost points

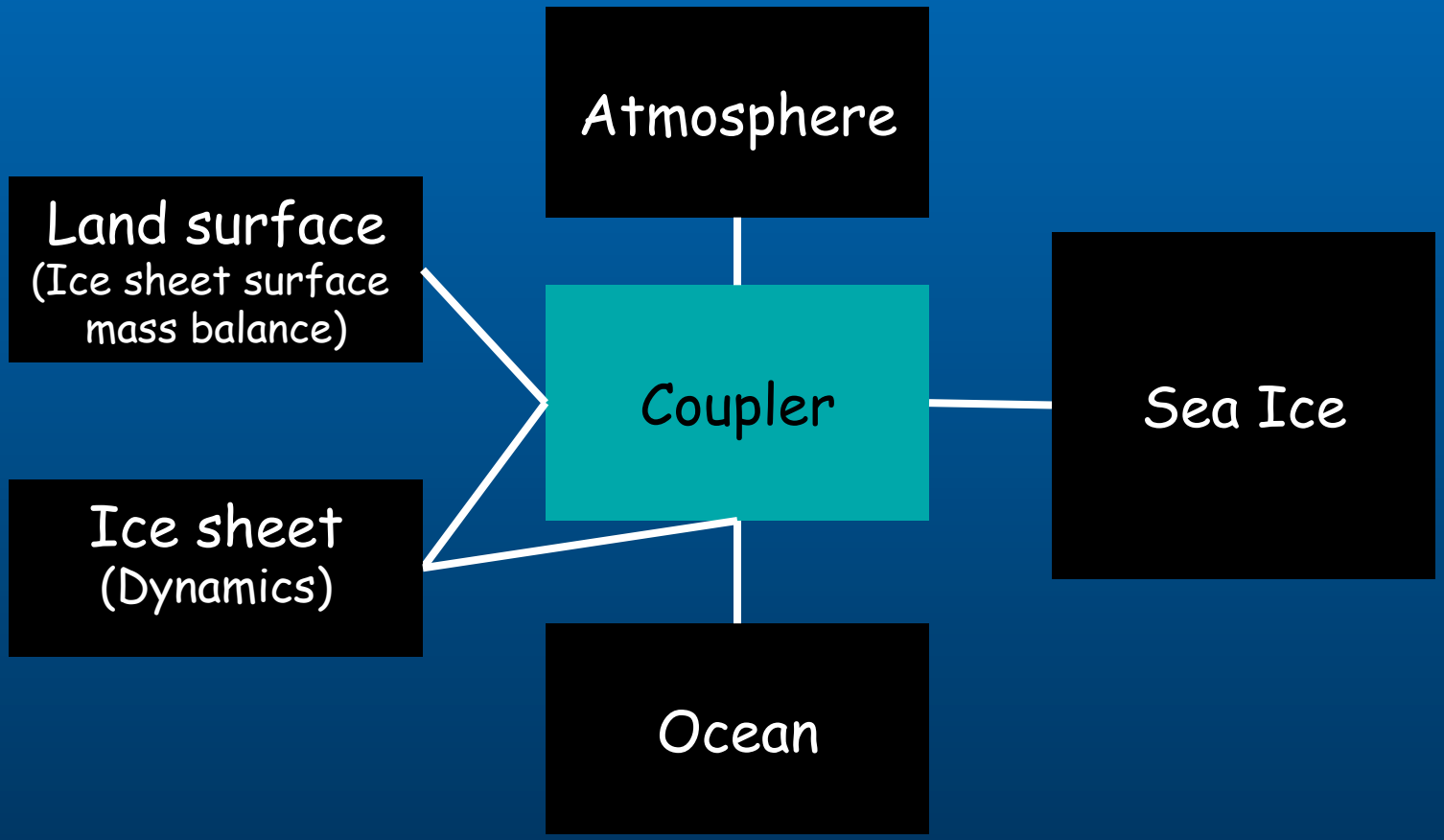
Ice-sheet/ocean coupling in CESM (in progress)

Ocean -> Ice sheet/shelf

- Basal heat flux
- Basal mass flux
- Ocean density (average over ice column)

Ice sheet -> Ocean

- Lower surface elevation
- Grounded/floating ice fraction
- Basal temperature info (for computing heat flux)



PISCEES: Predicting Ice Sheet and Climate Evolution at Extreme Scales

- PISCEES is a proposed 5-year, multi-institutional DOE project focused on computational improvements in ice sheet models and integration within CESM:
  - Further development of BISICLES and FELIX dynamical cores
  - Improved basal boundary condtions (including Coulomb friction)
  - Performance optimization
  - Verification and validation toolkit
  - Uncertainty quantification (using Dakota)
  - Full two-way coupling with land and ocean models

Possible collaboration with ISSM

- Standardized interfaces between ice sheet models and climate models
- Intermodel comparisons
  - Couple both ISSM and CISM to CESM and to the NASA global climate models.
- Ice-sheet/ocean interaction
  - Develop and test a variety of coupling methods.
  - Assess uncertainties of the combined ice-ocean system.